Sustainable City Enabled by Personal Rapid Transit

Peter J. Muller, P.E.
PRT Consulting, Inc.

1. Introduction

Ever since Henry Ford realized his dream of providing cars for the ordinary citizen, people have become more and more dependent on the automobile. Cars provide unprecedented levels of accessibility and mobility – even giving their owners a sense of freedom. Unfortunately modern cities have not been able to keep up with the demands of the car and many are now suffering the consequences.

Since widespread attempts to get drivers to switch to other modes like transit and bicycle have repeatedly failed, innovators have struggled to invent a better form of surface transportation. Automating cars is touted by some as a potential solution but the realities of accomplishing this in the near term are daunting.

Personal rapid transit (PRT) is now emerging as a potentially viable form of public transportation that has sufficiently high levels of service to attract significant numbers of drivers from their cars. PRT is extremely safe, requires little or no waiting and provides non-stop, seated travel. It uses much less energy than cars and requires only a relatively small infrastructure.

Recognizing the potential benefits of PRT, U.S. cities like San Jose, CA and Ithaca, NY are studying PRT applications. However these cities were designed and built around the automobile. They are specifically intended to facilitate the smooth operation of the car. Retrofitting these types of cities with PRT may alleviate some of their traffic problems and even allow some parking lots to be redeveloped, but will never realize all of the benefits PRT could bring.

The full benefits of PRT can only be realized in a city designed to leverage this exciting form of transportation from the beginning. Such a city could embody the dreams of many urban planners and be a truly delightful place to live.

Masdar City in the UAE is going further than any other towards leveraging the benefits of PRT. This paper takes their concepts into consideration and attempts to build on them. The paper outlines some automobile-caused problems, explores ways to develop a city designed to be free of cars, trucks and buses, summarizes potential benefits and hurdles to be overcome, and finally draws conclusions.

2. Cars are great but…

Cars are great but they are ruining our cities. From 1980 to 2005, the U.S. population grew by 35% (U.S. Census Bureau). During the same period, vehicle miles traveled grew by 95% (U.S. Department of Transport (DOT)). Alarmingly, transportation logistics costs grew by 160% and person-hours of delay (caused by traffic congestion) grew by 280% (U.S. DOT). While vehicle miles driven is growing at about three times the rate of population growth, the much faster rate of congestion growth indicates that highway capacity improvements are not keeping pace.

Despite the fact that we apparently need to be building even more highways than we are, infrastructure dedicated to cars already devours urban land. While the percent of land dedicated to roads and parking seldom falls below 20, it is easy to find locations such as that depicted in Figure 1 where roads and parking occupy as much as 50% of land use.

Figure 1. Urban area devoted to roads and parking in this photo is 48% (PRT Consulting)

Safety is a huge issue with surface transportation. The 41,059 highway deaths (U.S. DOT) in 2007 is almost as many as the 58,236 total U.S. deaths in the entire Vietnam War (Wikipedia). The average monthly deaths in 2007 (3,421) is higher than the 2,973 killed on 9/11 (Wikipedia). While electronic advances are touted as having the potential to improve road safety, some, such as texting, can have the reverse effect.

Surface transportation accounted for 47% of the net increase in total U.S. emissions since 1990 (U.S. Environmental Protection Agency (EPA)). Transportation accounts for 34% of all U.S. greenhouse gas emissions (U.S. EPA) and it alone uses more oil than all other uses combined.

3. Transit is not the answer

Americans simply do not like to use transit. From 1989 to 2007, U.S. transit mode share rose a mere 0.5% from 4.6% to 4.9% (U.S. DOT) despite numerous incremental improvements. Even if people could somehow be persuaded to use it, transit uses about the same energy per passenger mile as cars and it is not much safer, killing fewer but injuring more per passenger mile (U.S. DOT).

The latest push towards so-called high speed rail may help inter-city travel but will do little or nothing for intra-city travel. High speed rail stations are likely to create yet another artificial concentration of people in both time and space.

4. Automated highways are not the answer

While Randal O'Toole claims that automated highways will solve many surface transportation problems, he overlooks some serious issues such as the fact that authorities impose much higher safety standards on new automated systems than they do on legacy manual systems. A major problem stems from the requirement for a following vehicle to stop before colliding with a preceding vehicle which suddenly stops. O'Toole is correct in that computers and electronic sensors can do a better, quicker job of perceiving and reacting to such an emergency. However, the problem arises where the rubber meets the road. In good weather with good road surface conditions, it is likely that automated controls can operate safely at headways in the order of one second at 65mph. This would be a considerable capacity improvement over present highways at greater headways and would provide a lane capacity of 3,600 vehicles per hour. The problem is that these headways become difficult to achieve if the pavement is wet, and impossible if it is covered in snow or ice. Sensing and adjusting for slippery pavements is presently done imperfectly by drivers who accept the responsibility of doing so. An automated system will be required to sense such conditions perfectly. In addition, it will always be required to assume the worst case scenario. This means that speeds and capacity are likely to drop dramatically at the least sign of slippery pavement. Thus an automated roadway system may have higher capacities in good weather but would likely clog up the minute the weather turned bad. Such a system would be satisfactory only in a very few cities blessed with suitable weather.

Another problem is that automated vehicles will have to respond to unexpected obstacles. Unless roads are rendered inaccessible to pedestrians, cyclists, animals, etc., (possible on freeways but unlikely on expressways) sudden intrusions will have to be dealt with. An errant pedestrian could thus cause emergency braking and disruption similar to what would be caused presently. What would this do to initiatives to promote walking and cycling? In addition, an automated system would be susceptible to a tumbleweed being mistaken for a pedestrian and causing a jam up.

O'Toole speculates that driverless cars will be able to operate at higher speeds. This sounds intuitively correct, but, in fact, the reverse is true. In order to meet the stringent safety criteria discussed previously, speeds are likely to be reduced, not increased, for any rubber-tired system. The 2getthere system has operated driverless vehicles in general traffic. To do this safely, they operated at 15 mph.

O'Toole greatly underestimates the problem of introducing driverless vehicles into our road system. Even if the end state was eminently desirable, the transition required to get there is very problematic.

Each time a new element of driver assistance is introduced, it is accompanied by potential detriments. GPS navigation systems are now quite ubiquitous as are cellular phones. It is now widely recognized that texting while driving is highly dangerous. However, interacting with a GPS system is a form of texting that is highly distracting, yet (thus far) seemingly ignored by authorities. As we provide incremental assistance to drivers, the unintended consequences are likely to present continual setbacks. Distraction is a major concern. The more automated the driving process becomes, the more tempted drivers will be to be distracted. Thus the automation process is likely to suffer a series of setbacks and delays as each unintended consequence caused by the human/computer interface is dealt with.

A major complication with introducing driverless vehicles is that it will be difficult to do this in any but an incremental fashion. The best way to automate cars would be to do so in one fell swoop – avoiding the difficulties described in the preceding paragraph. However, it is difficult to imagine a scenario where all cars are driven one day and driverless the next – even in a confined area. This means that driverless cars will have to interact with driven cars (and worse – trucks) for an extended period of time – something that will be extremely difficult to accomplish. In addition, the more expensive driverless cars will initially have few advantages over the driven cars. Until driverless cars are in the vast majority, the characteristics of driven cars will continue to dominate, traffic jams will continue, and driverless cars will bring little benefit. Who is going to pay extra for a driverless car that brings few extra benefits?

The problems with automobile-based transportation go far beyond those O'Toole speculates will be solved by driverless cars. Some problems that will not be addressed include:

- Real estate devoured by roads and parking lots. Since roads will still need to accommodate trucks, lane widths cannot be reduced much. Since congestion has been increasing at eight times the rate of population growth, as discussed previously, dramatic capacity improvements will be required before road expansions are no longer needed. Automating cars will not change the fact that each car is only used on average for about 12,000 miles per year or 33 miles per day. This results in an enormous requirement for parking spaces – at home, work, shopping and recreation areas as cars wait around for their drivers.
- Severance caused by roads will not be diminished. Communities will continue to be divided by highways.

- Since cars will remain personal property, automating them will not reduce the significant resources spent on building and owning them.
- Automating vehicles (even trucks) will not significantly address the costs of logistics (moving goods) which are increasing at four times the rate of population growth as discussed before.
- Automating cars will do little to improve livability. The roads and parking lots required to accommodate cars will continue to separate and divide shops, hospitals, university facilities, etc. making it difficult to walk between them and essential to own a car.

O'Toole is to be applauded for his valiant attempt to rescue the automobile. However, Lowson has demonstrated that transportation revolutions are historically accompanied by new infrastructure.

5. What is needed

Try as we might, it is clear we cannot build our way out of the rapidly growing congestion we face. Dreams of increasing capacity by automating highways will not come to fruition for many years. Other solutions that do not restrict automobile use also do not have widespread positive impacts. Transit is clearly not the solution desired by most Americans. It is time to accept that a new form of transportation based on new infrastructure is required to save ourselves from a highly problematic road system and a dysfunctional transit system that nobody wants to use. Could personal rapid transit (PRT) be the solution needed?

PRT uses driverless automobile-size vehicles (transportation pods or T-Pods) in a practical way that is already being implemented around the world. PRT vehicles operate on guideways separated from other traffic and from pedestrians. Stations are off-line allowing non-stop origin-to-destination travel. This also allows systems to have numerous stations without impacting overall travel speeds. This in turn means that walking distances are short. Empty vehicles are pre-positioned in stations where demand is anticipated resulting in very short wait times. In summary, PRT is a form of transit that:

- Waits for you
- Always provides you with a seat
- Provides non-stop trips
- Has short walking distances

PRT is now commercially available from three different vendors (see Figure 2). Many studies have shown that, because of its high level of service, (it is much more like a car than like transit) PRT could attract significant numbers of drivers from their cars. It has the ability to dramatically reduce (but not eliminate) our reliance on the automobile and facilitate the development of cities that are radically more livable than the car-dominated ones we presently live in.

Figure 2. Left to right – PRT systems from 2getthere, ULTra and Vectus

In addition to the above service benefits PRT:

- Is 100 times safer than cars
- Uses less energy than other systems
- Has low infrastructure needs
- Can also carry freight
- Is economical to operate

The following table provides the author's estimate of the impact of various transportation solutions on the problems discussed above.

Table 1. Comparison of Positive Impacts

	High speed Rail	Light & Commuter Rail	Street Cars	Demand Management	Hybrid cars	Electric cars	Automated Highways	PRT
Accidents	1	1	0	0	0	0	2	2
Congestion	0	1	0	1	0	0	0	2
Energy use	0	0	0	1	1	2	1	2
Cost	0	0	0	0	0	0	0	1
GHG	1	1	1	1	1	2	2	2
Logistics	1	0	0	1	0	0	1	1
Severence	0	0	0	1	0	0	0	2
Real estate	0	1	0	0	0	0	1	2
Walkability	0	1	2	1	0	0	0	2

Key:

No positive impact	0
Some positive impact	1
Significant positive impact	2

Most PRT implementation efforts, such as current studies in San Jose, California, Ithaca, New York and Fort Carson, Colorado, are focused on leveraging its unique attributes to improve surface transportation in existing cities and facilities designed originally to accommodate the automobile. While this is a very necessary endeavor because of the extensive investment we have in existing infrastructure, it is somewhat akin to putting lipstick on a pig. We need to start thinking in terms of how we would design and operate cities that no longer need to accommodate the automobile.

6. Sustainable City Concept

This section strives to lay the conceptual foundation for a car-free city or community. The major issues are addressed sufficiently to make the point that, while totally car-less living is probably not attainable (and may not even be desirable), car-free communities are certainly attainable and could be very desirable. Clearly many details will have to be worked out and hurdles overcome before car-free communities can be developed. However, it should be pointed out that the first such modern car-free community is under construction in Masdar in the UAE.

Simply ridding cities of automobiles may improve sustainability but is insufficient to also improve the quality of life. If we can improve both the quality of life and sustainability we may develop the opportunity to continue on the path to increased prosperity while simultaneously reducing our environmental impact. Our vision for a car-free community should therefore be along the lines of: *sustainable communities with exceptionally attractive living environments for all*.

In order to meet this vision, most, or all of the following objectives will have to be met:

No cars, trucks or busses. This can be accomplished by serving intra-community travel needs with a PRT system and leaving cars, motor homes, boats, etc. on the periphery.

A dense PRT network of guideways. Spacing between guideways could well end up being less than ½ mile (0.8km). As depicted in Figure 3, guideway concepts will probably range from underground to fully elevated.

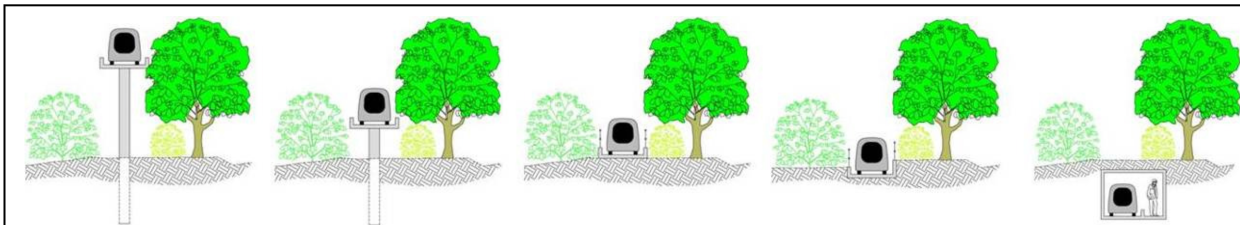

Figure 3. Guideway concepts

A station for every building. This is readily accomplished in areas of dense development. Figure 4 depicts a low-capacity building station. The guideway could be considered to be a low-speed station guideway and could serve bays on adjoining buildings before connecting back to the main guideway. Figure 5 depicts how a cluster of eight houses could share a station in the back yard of each. Service all the way into a house could potentially be provided (possibly at a premium) by having the T-Pod leave the station guideway and creep along a private guideway.

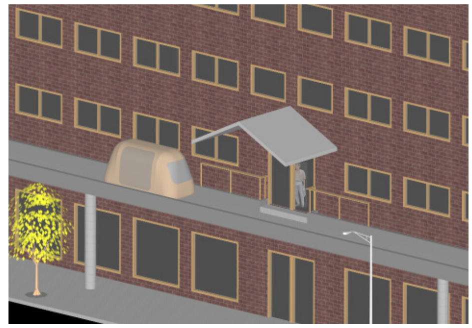

Figure 4. Low capacity building station

Links to parking and transit. The PRT system should provide convenient links to access private vehicles at peripheral parking lots as well as to transit systems serving legacy portions of the city.

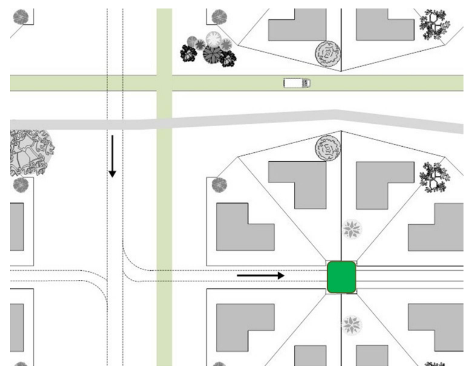

Figure 5. Shared station for single family homes

PRT freight vehicles. All freight should be handled by vehicles similar to that depicted in Figure 6. These vehicles should be capable of accommodating items such as king-size beds. However, in order to avoid vehicle size creep, very large items such as grand pianos should not be accommodated. These very large items can be delivered at low speeds by special permit along aggregate-turf roadways. These are low-use roads constructed of a gravel/topsoil mix with a turf surface. Alternatively special low-impact vehicles could utilize footpaths for occasional access. Figure 5 depicts both aggregate-turf roadways and footpaths.

Figure 6. 2getthere's freight vehicle

Refuse and mail on PRT system. The system should be designed to automatically pick up refuse and deliver mail.

All buildings sprinkled and equipped with built-in ladders. This serves the dual purpose of reducing fire damage and reducing the need for mobile fire-fighting equipment.

Emergency responders use specially-equipped T-Pods. Fire fighters and emergency medical technicians travel in specially equipped T-Pods (or groups of T-Pods) capable of accommodating mobile equipment and gurneys.

Home automobile access by special permit. In order to allow people freedom to do things like work at home on their vintage cars, permits should be available to allow them to occasionally drive at low speeds on the footpaths or aggregate-turf roadways to access their homes.

All T-Pods under continuous CCTV surveillance. This standard PRT requirement should help dramatically reduce crime. Robberies and kidnappings will be difficult when the getaway vehicle is a T-Pod under surveillance.

7. Advantages

Sustainability. PRT systems use about a third the energy per passenger mile of other transportation systems (U.S. DOT, various PRT vendors). In addition, since they are all powered by electricity, the system sustainability can be readily upgraded by upgrading the sustainability of the power source. Battery powered PRT systems could be more conducive to intermittent power sources such as wind and solar due to the capability of batteries to store energy. PRT guideways, stations and maintenance/storage depots require substantially less impermeable surface area than the roads, garages and parking lots they would replace. This would result in less (often polluted) rainfall runoff and less heat island effect.

Cost less to build and operate. The PRT cost would be more than offset by the cost of roads, parking and garages no longer required. The reduction in auto accidents and crime would reduce response costs. PRT’s infrastructure carries light loads and previous examples have been cost-effective to maintain.

Low crime rate. Just eliminating getaway cars should reduce robberies. Kidnapping would become very difficult with all T-Pods under continuous CCTV monitoring. Travel on the PRT system should be virtually crime-free as evidenced by 35 years of experience at Morgantown where the system is made to appear as if it is monitored even though monitoring is actually restricted to the stations only.

Improved health. Health improvements should result from the elimination of local auto emissions. In addition, the entire outdoors will be a safe environment for walking, biking and playing.

Improved wealth. According to Arrington, good transit access results in commercial land premiums ranging from -4% to 103% and residential housing value premiums ranging from 20% to 45%. Households that can eliminate a car will save $7,086 to $11,473 annually (American Automobile Association). Every mile traveled by PRT will save about $0.25. According to Bina, people will pay $4,700 more for a house per minute of commute time saved.

Improved safety. The Morgantown PRT system has completed over 140 million injury-free passenger miles (Morgantown PRT). According to Muller, Morgantown is about a hundred times safer than conventional transit.

Table 2 shows the importance of various housing/location attributes people consider when purchasing a home, according to Bina. It also shows which ones will likely be positively impacted in a car-free community such as discussed here.

Table 2. Importance of Housing & Location Attributes

Housing/Location Attribute	Mean Score	Positive Impact
Price	3.72	✓
Attractive neighborhood appearance	3.59	✓
Investment potential or resale	3.40	✓
Perception of crime rate in neighborhood	3.36	✓
Number of bedrooms	3.29	
Commute time to work (or school for full-time students)	3.12	✓
Noise levels	3.08	✓
Lot size/yard size	2.86	
Access to major freeway(s)	2.70	
Social composition of neighborhood	2.69	
Distance/travel time to shopping	2.53	✓
Quality of local public schools	2.52	✓
Views	2.49	✓
Neighborhood amenities/recreational facilities	2.45	
Closeness to friends or relatives	2.25	✓
Distance to medical services	2.11	✓
Distance to local public schools	2.04	✓
Access to bus services	1.57	✓
Physical disability accommodations	1.47	✓

Source: Bina et al. Key: 1 = not at all important; 4 = very important

8. Hurdles to be Overcome

Inertia. Probably the biggest hurdle to be overcome is simply human reluctance to change. While home buyers and builders may be quite highly motivated to accept the changes posited here (once they understand them), city building and zoning departments may not. Some of the changes proposed will run directly counter to current codes and could thus require considerable flexibility from officials.

Lack of prior examples. While new city planning concepts, including automobile-free ones, have been attempted before, none have been enabled by PRT. There is thus little prior experience to learn from. Masdar City in the UAE is an exception. However, the approach at Masdar is very unique with a subgrade PRT system heavily constrained by non-continuous alignments and subject to emergency vehicle incursions.

Problems with PRT. PRT's long history of unsuccessful startups will hopefully soon be overcome by more than one successful deployment. However continuing delays suffered by systems about to be deployed are playing into rumors of PRT still being subject to serious problems.

Small demonstration not feasible. In order for a demonstration community to be built implementing most of the features described here, it would have to include a fairly large number of houses. Such a demonstration would therefore cost a substantial amount and entail quite considerable risk.

Technology hurdles. Some technology requirements discussed here have yet to be developed/optimized. However, it is anticipated that these hurdles can be relatively easily overcome.

9. Conclusions

The numerous benefits appear to outweigh the hurdles to be overcome. The potential for people to reduce their carbon footprints while substantially raising their living standards could result in a strong desire among a substantial number of people to implement this concept. This coupled with the fact that large home builders could derive considerable benefit may be sufficient to overcome inertia and the fear of change.

It is suggested that the exercise of planning car-free cities enabled by PRT is worthwhile for two reasons: 1) it could result in such cities actually being built and, 2) some of the concepts developed could be found to be applicable when retrofitting existing cities.

Wouldn't a city where people could live and work in a park-like setting with increased well-being and reduced crime and pollution be almost perfect?

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